

Lift and the Launch Angle

Introduction

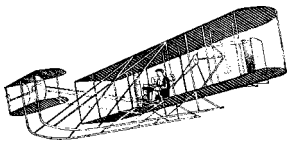
This activity is designed to introduce students to the concept that the launch angle affects airflow around the wing, and thus affects the amount of lift generated by the wing. This 3 to 7 day elementary activity is designed for students in grades 4 – 8. It is primarily a hands-on experiment complemented by a series of photos depicting the experiment set up, a student informational reading, comprehension worksheets, vocabulary exercise, experiment guidesheets, collaborative guide, and a follow-up exercise connected to the Wright Brothers' work.

Grade Levels: 4 - 8

Overview

The Wright Brothers had to solve many problems during their quest for flight. They had to identify and understand complex concepts and their interrelatedness to each other. One of the many problems they had to solve was determining the best angle of attack for their airplane in order to prevent a stall during flight (which could have disastrous results). In order to collect data to determine the most effective airfoil shape, airflow changes and air pressure changes, etc., they tested their original ideas by constructing their own wind tunnel.

This activity aims to help elementary students achieve a greater understanding of lift and the effects of the launch on lift, by allowing them to perform a hands-on test that will demonstrate the aeronautical principles in action. They will construct a pre-fabricated (i.e., "store bought") balsa wood or Styrofoam™ glider and use a standardized launcher to perform tests that will vary the launch angle. They will observe, and record their findings. From this data they will determine for that particular aircraft model what its best launch angle is (the angle that gives the greatest lift and farthest flight). Follow-up to this activity includes solving a similar problem using a scenario about the Wright Brothers, as well as activities utilizing the wind tunnel data from the 1903 Wright *Flyer* replica tests.



The “Student Handouts” section consists of a student reading regarding the aeronautical concepts of lift, wings, angle of attack and stall angle, as well as information regarding how the Wright Brothers dealt with these issues. It also consists of comprehension and vocabulary worksheets, guidesheets for performing the launch angle test and an extension worksheet relating this to the Wright Brothers.

All of these activities are designed to connect easily with the wind tunnel tests to be performed on the 1903 Wright *Flyer* replica. The data from these tests will be posted, and your students will be able to access the data, then graph it, analyze it, and inform the AIAA pilots of the best angle of attack at which to fly, as well as the stall angle.

Key Questions

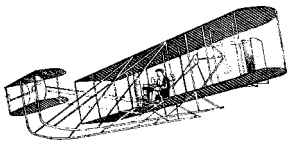
- What is the best launch angle for this model?
- Why do some airplanes never fly at a vertical angle of attack?
- How can we visually represent an airplane's launch angle?
- Can we mathematically determine an airplane's optimum launch angle given key information?
- How does an airplane's launch angle affect its lift and flight distance?
- Is there an angle at which an airplane's wing can no longer generate lift?

Time Frame

Three to seven class periods of 45 to 60 minutes each.

Getting Ready

1. Run all multiple copies of each student handout.
2. Decide where the launches will take place and secure the area.
3. Purchase and assemble gliders (Teacher or students or parent volunteers build them)
4. Gather launcher materials.
5. Assemble launchers and make a few practice launches on your own.
6. Make sure your class understands how to measure using a ruler, tape measure and a protractor.



Materials

For each student:

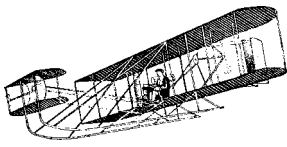
1. Student Reading
2. One student comprehension worksheet based on the student reading
3. One vocabulary list
4. One vocabulary crossword puzzle

For the class (It would be optimal to have 3 to 5 launchers for the experiment.):

1. 1 "homemade" launcher:
 - 2 tack nails or push pins
 - 1 large-size, heavy-duty (flat) rubberband
 - 1 protractor (attached to the base board with tape and used to measure the angle of the launch board)
 - 1 piece of quarter inch thick plywood, dimensions of 1 foot by 2 feet (serves as the base board which has the protractor and nails/pins attached to it)
 - 1 piece of strong cardboard 12 x 6 inches used as the launch board
 - 3 different sized pieces of cardboard used to manipulate the angle of the launch board:
 - 2 x 6 inches (10-degree angle approximately)
 - 3-1/2 x 6 inches (20-degree angle approximately)
 - 5 x 6 inches (30-degree and variable angle approximately)
 - large room free from breezes and obstacles
 - tape measure

For each team of students (3 to 4 students per team):

1. One commercially-made balsa wood or Styrofoam glider (no propeller models)
2. One launcher (see #1 under "For the Class")
3. Team Members and Their Roles
4. Experiment Procedure Card and Data Sheet



Classroom Activity

Session 1

Familiarize your students with the Wright Brothers and their work by reading a story about their aeronautical achievements, reviewing the Web site's timeline, watching a video, visiting other Web sites featuring information about the Wright Brothers, etc. Make sure you touch on the following processes and methodologies the brothers used in their pursuit of flight: research method, scientific method, hands-on experiments, controlled flight tests, wind tunnel tests, etc.

Session 2

Use the student reading to discuss the four forces, air, airflow and wings, launch angle angle of attack, and the stall angle.

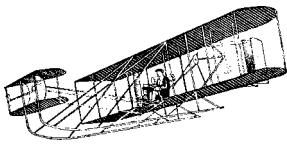
Show pictures or video of airplanes in subsonic flight and discuss the aeronautical concepts.

Pose and discuss the questions:

- Why do airplanes take off at an angle?
- Does the angle at which the wings meet the airflow have an effect on lift? What is that effect?
- Is there an optimal (best) launch angle for lift?
- Is there a launch angle at which the wings stop generating (creating/making) lift?
- How can we find out?

Discuss possible ways to answer these questions.

Lead them to the launch angle experiment found on the student experiment guidesheets. Tell the students that during the next class session they will be making some observations about the launch angle and lift using some gliders.



Session 3

Have students assemble their commercially-made gliders and give them some playtime with the gliders.

Distribute the Experiment Procedure Card and Data Sheet. Review the experiment procedures with the students, emphasizing the importance of pulling the rubberband to its agreed-upon distance of 3 inches (not shorter and not longer).

Review how to measure the launch angle with a protractor.

If you have only one launcher or only enough for one-half to one-third of the class to perform the experiment at a time, then it is suggested the teacher set up workstations. Have some students perform the experiment, others answer the questions on the student reading worksheet, work a Wright Brothers timeline activity sheet from the Web site, or engage in one of the Wright Brothers' puzzles from the Web site or work the vocabulary crossword puzzle.

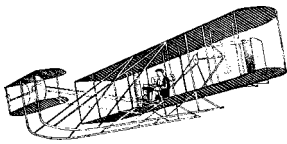
Session 4

Have students graph their results and prepare a conclusion for their experiment using the measured angle for one axis and the distance flown for the other axis.

Activity Wrap-Up Session (Session 5)

Have the students post and share their results. Discuss any noticeable correlation between the angle and the amount of lift measured in the distance flown. If there is a noticeable correlation, see if the students, given an angle, can predict if the distance flown would be greater or less.

Based upon the students' results, have the students (acting as an aeronautical scientific community) reach consensus on what the optimal angle of attack for lift is, and what the stall angle is (for this particular model). Then using the launcher, demonstrate the agreed-upon results.



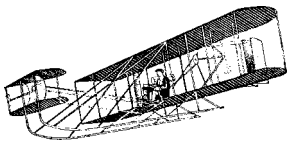
Relating this to the Wright Flyer (Session 6)

Read the last section of the student reading regarding the Wright Brothers and their aeronautical work.

Discuss the critical thinking problem “Know All the Angles” and allow time for the students to solve it.

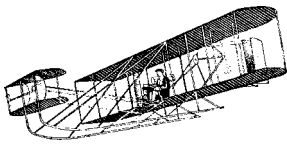
More Activity Ideas

1. See the Web site for additional activities offered for hands-on aeronautical experiments.
2. Purchase two different models for the test, and compare results.
3. Change the aim of the experiment by discussing the effect thrust has on the model. Have students vary the amount of thrust the model receives by changing how far back the rubberband is stretched before release. Remember to have the launch angle remain the same!
4. Download and make copies of the airflow images that show how the airflow over a wing changes from laminar to turbulent at various angles of attack. Discuss the meaning of the information visualized by the images, as well as the importance of research in the computational fluid dynamics field.

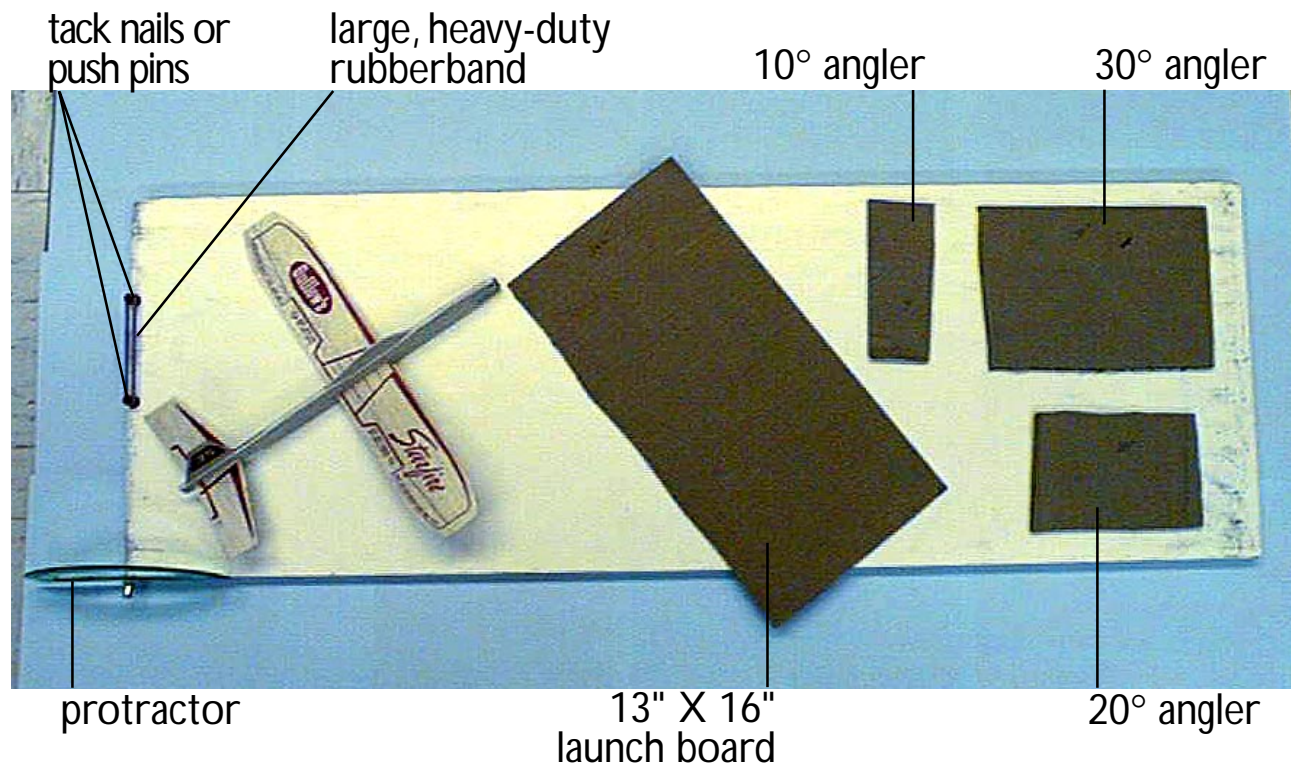


Procedural Considerations for Teachers

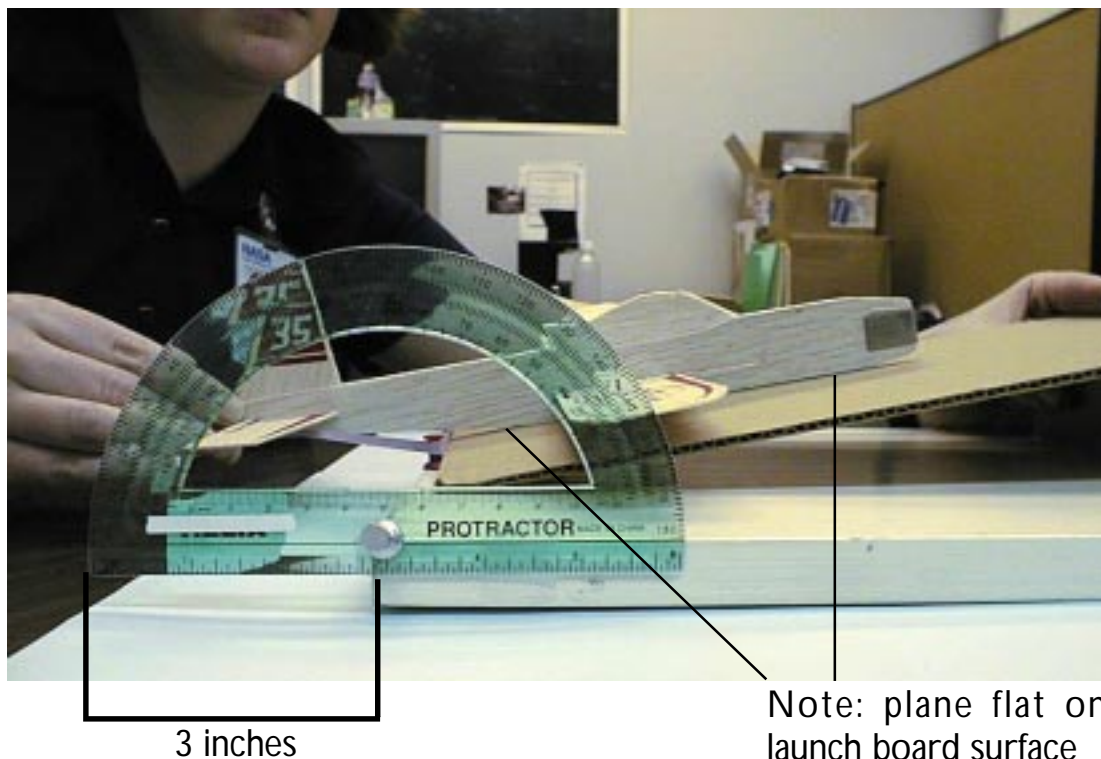
1. Have the launchers pre-assembled for your class to use.
2. Set up the launcher stations beforehand with tape measure laid out along flight path.
3. Purchase and construct an extra airplane or two as they will suffer some structural damage during the tests.
4. Tape the protractor so that the circle is at the corner of the board and the line matches the top edge of the board (see photos following pages). This will have half of the protractor hanging off the edge of the base board, exactly three inches.
5. Emphasize that the rubberband is to be pulled back exactly three inches for each trial.
6. Emphasize that the flight distance is measured from the back edge of the base board to the first point of contact that the airplane makes with the ground.
7. Have the pilot always check with the launch manager before launch to make sure that the airplane is not “nosing up” off the launch board, but is flat against it. The pilot might have to gently press down on the fuselage of the airplane, releasing upon the snap of the rubberband at launch.
8. After each flight, the pilot needs to make sure that all parts of the airplane are properly positioned: tail is securely in place and wings are set in the “back” position and centered.
9. Suggestion for launching: If using the same model airplane as pictured, place the rubberband into the slit at the rear of the airplane and pinch the rear end of the fuselage between your index finger and thumb. Then, pull back gently to the required three inches. Gently press down on the front part of the fuselage (around the cockpit area) to ensure that the airplane is lying flat against the launch board.
10. The teacher should designate the following roles for each team:
 - Flight Data Recorder: team member who records the angle and distance measurements for each flight;
 - Pilot: team member who is in charge of launching airplane, making sure that all airplane parts are securely in place before launch, pulling rubberband back exactly three inches and keeping the fuselage of the airplane flat against the launch board;
 - Launch Manager: team member who is in charge of determining and maintaining the angle of attack, make sure the base board does not move during the time the rubberband is being pulled back, as well as monitoring the airplane’s contact with launch board;
 - Spotter: team member who monitors airplane’s flight and spots the airplane’s first point of contact, then measures the distance, reports measurement to the Flight Data Recorder, and then returns the airplane to pilot.

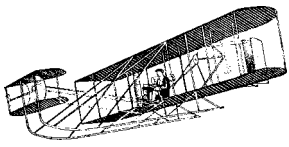


Materials

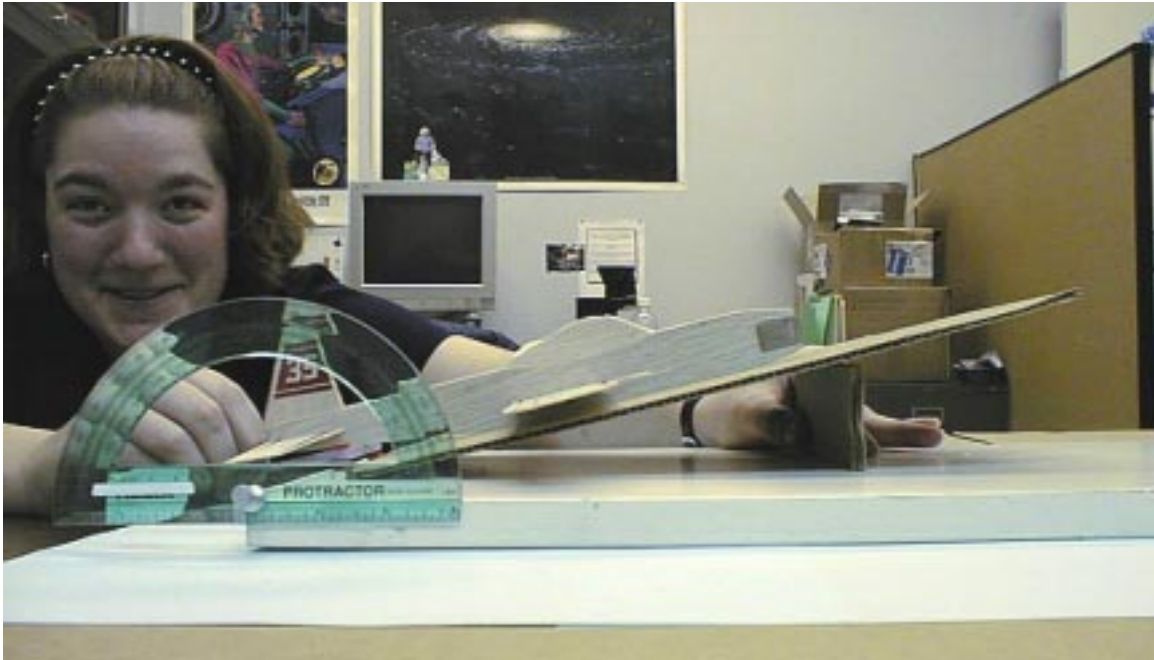


Proper Launch Technique



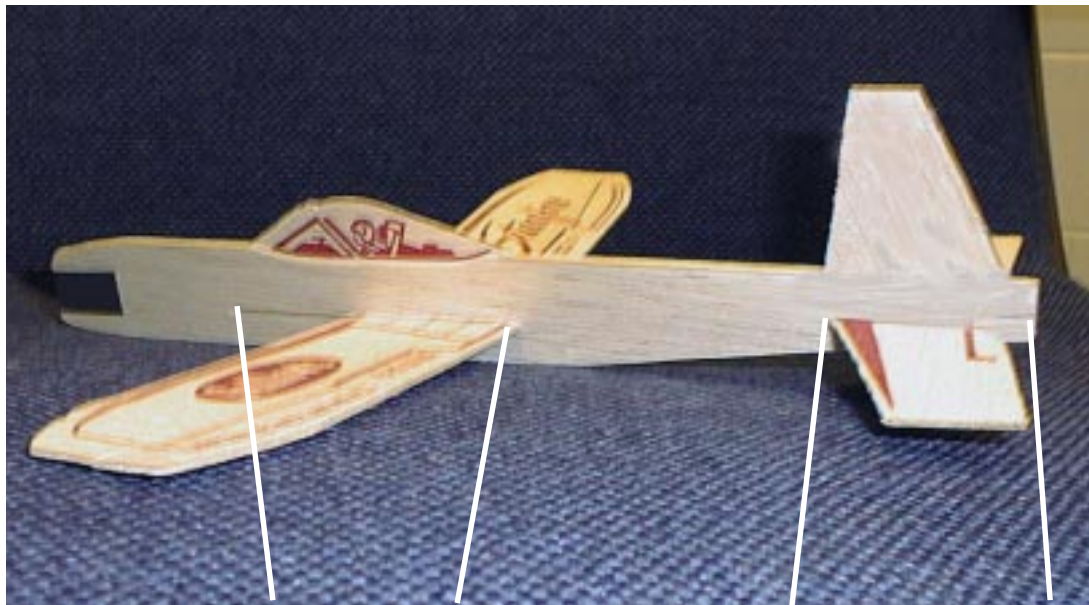
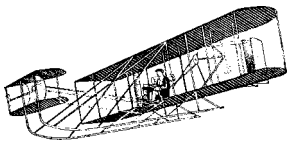


10° Launch



30° Launch





tail
horizontal
stabilizer
in front
position

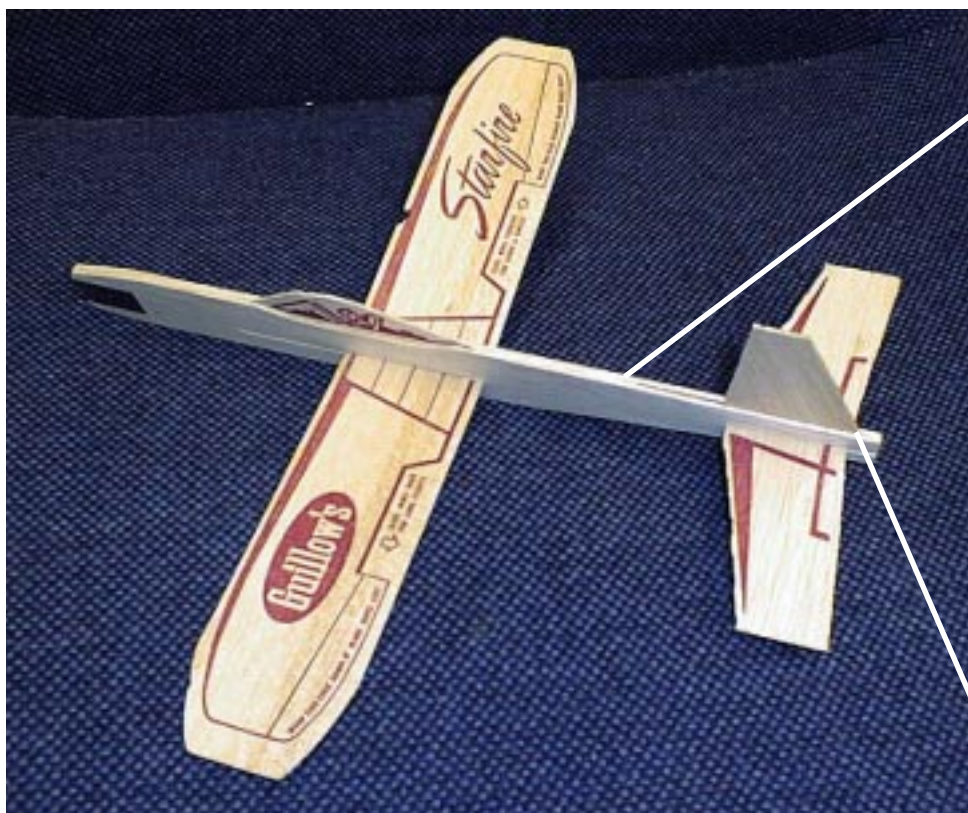
front

back

front

back

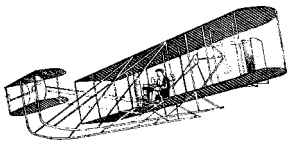
wings in "back" position



front

rudder in
"back"
position

back



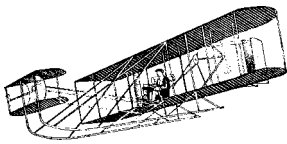
Background for Teachers

Prerequisites

- Measurement of distances using a ruler and a tape measure.
- Measurement of angles using a protractor.
- Creating graphs to depict raw data.

Vocabulary

- **aerodynamic:** Having a shape that allows for smooth airflow and lift.
- **air:** A mixture of gases that surrounds the earth; this mixture is made up of molecules that take up space and have weight.
- **airflow:** The motion of air molecules as they flow around an object, such as a wing.
- **airfoil:** An object with a special shape that is designed to produce lift efficiently when it is moved through the air.
- **air pressure:** The force created by air pushing on a surface.
- **angle of attack:** The angle of a wing to the oncoming airflow.
- **camber:** The curve of an airfoil.
- **drag:** The force that resists the motion of the aircraft through the air.
- **force:** A push or pull in a certain direction, that can be measured.
- **laminar flow:** The smooth flow of air around an object.
- **launch angle:** The angle at which an airplane (most efficiently) takes off.
- **leading edge:** The front edge of an airfoil.
- **lift:** Upward force produced by air passing over and under the wing of an airplane.
- **stall:** A breakdown of the airflow over a wing, which suddenly reduces lift.
- **stall angle:** The angle where the wing meets the oncoming airflow and the wing stops generating lift.
- **thrust:** A force created by the engines that pushes an aircraft through the air.
- **trailing edge:** The back edge of an airfoil.
- **turbulent flow:** Airflow around an object that does not flow in a smooth stream, but swirls about.
- **weight:** A force of gravity acting on an object.



Background for Teachers (continued)

Skills

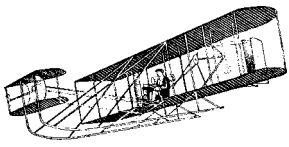
- Reading for meaning
- Observation of flight
- Physical measurement of angles and distances as they pertain to the experiment
- Data collection
- Constructing data tables
- Graphing data

Concepts

- Air is composed of molecules and has mass and weight.
- Airflow affects air pressure.
- Shape of the wing affects airflow and air pressure.
- Faster airflow over the wing and slower airflow under the wing generates lift. (Lower air pressure over the wing and greater air pressure below the wing; Bernoulli Principle)
- The stall angle is the angle of the wing in relation to the airflow, at which point the wing stops generating lift.
- Air flowing smoothly over the wing is laminar airflow.
- Air flowing over the wing that separates from the wing shape and swirls oddly is called turbulent airflow.
- When turbulent airflow is greater than laminar airflow, the wing stops generating lift.
- The angle at which the wing meets the airflow is a factor in determining the amount of lift the wing will generate.

Processes

- Using the scientific method to solve a problem or answer a question
- Analyze and evaluate data



Student Handouts

- Student Reading
- Student Comprehension Worksheet
- Vocabulary List
- Vocabulary Crossword Puzzle
- Team Members and Their Roles
- Experiment Procedure Card and Data Sheet
- Know All the Angles